I – Research Problem Title (04-GS108)

Validating the Durability of Corrosion Resistant Mineral Admixture Concrete

II – Research Problem Statement

Question: How do we validate the adequacy of mineral admixture concrete currently specified by the Department for mitigating corrosion caused by exposure to chlorides from salt water and applications of deicing agents?

The California Department of Transportation (Department) has developed concrete mixes for corrosion mitigation of structures to meet the AASHTO Load and Resistance Factor Design (LRFD) Bridge Specification requirement of a 75 year design life. Mix designs are based on research conducted by others outside of the State of California. Research to date is incomplete, and is not specific to the materials and exposure conditions that exist in California. Additional research is needed to validate design assumptions that influence the expected service life of mitigation measures.

III – Objective

To validate chloride diffusion coefficients of concrete mix designs currently specified by the Department for corrosion mitigation, and verify the adequacy of existing mitigation measures.

IV – Background

Prior to 1963, concrete cover requirements were specified based on the structural member type, with additional "unspecified" cover required for members with direct exposure to seawater. Department Specifications were later modified to include a "specified" amount of increased concrete cover for structures exposed to waters with 10,000 ppm or greater chloride concentration. These requirements were eventually listed in Bridge Design Specification (BDS), Article 8.22, Protection Against Corrosion.

In the year 2000, requirements of the AASHTO LRFD for a 75-year design life, and advances in concrete technology prompted significant changes to BDS, Article 8.22. The Department took the approach of using the diffusion rate of chlorides through concrete to determine the amount of concrete cover required for a specified design life. This approach allowed a rational method for determining the amount of concrete cover needed, based on the amount of chlorides present in the service environment, and the required design life. Mineral admixture concrete was used to reduce the permeability of concrete to chlorides while keeping the concrete cover requirements at reasonable thicknesses.

The Department's work to date in developing corrosion resistant concrete mixes has been based on diffusion coefficient data for low permeability, mineral admixture concretes selected from available literature. Diffusion coefficients of chloride through concrete vary depending on mix design parameters (cement/water ratio, mineral admixture content, etc), length of exposure to chlorides, method of chloride analysis, and exposure condition (submerged, splash, atmosphere, etc.). Variations in solving Fick's diffusional model exist to account for various exposure conditions, but are not standardized. Additional research is needed to standardize test methods for determining diffusion coefficients, determine diffusion coefficients for concrete mixes used by the Department, and to evaluate mixes designed with new admixtures.

V – Statement of Urgency and Benefits

A. Support of the Department's Mission/Goals

(Improving Mobility: Safety and Reliability*)* The Department's bridge inventory includes numerous structures with exposure to corrosive salt conditions such as marine salt water and Area III deicing regions. Contact with corrosive salt usually results in the need for costly and difficult repairs such as the removal of unsound concrete, replacement of severely corroded reinforcement, deck rehabilitation including pothole repair and/or deck replacement, etc. Cost effective corrosion mitigation strategies are needed to produce safe and reliable structures for the traveling public.

B. Return on Investment:

A recent report sponsored by the FHWA, and performed in conjunction with the National Association of Corrosion Engineers (NACE) and CC Technologies has estimated the annual direct cost of corrosion for highway bridges at $8.3 billion (FHWA-RD-01-156), consisting of $3.8 billion to replace structurally deficient bridges over the next ten years, $2.0 billion for maintenance and cost of capital for concrete bridges, $2.0 billion for maintenance and cost of capital for concrete substructures (minus decks), and $0.5 billion for maintenance painting of steel bridges. Currently, mitigation measures for reinforced concrete used by the Department are based on available diffusion research that is incomplete, and does not represent materials and exposure conditions seen in California. Additional work is needed to better define the strategies used by the Department to design concrete structures with adequate corrosion mitigation measures for a relatively maintenance free design life.

VI – Related Research

1. Al-Amoudi, O.S.B., Malslehuddin, M., Asi, I.M., "Performance and Correlation of the Properties of Fly Ash Cement Concrete," Cement Concrete, and Aggregates, CCAGDP, Vol. 18, No. 2, 1996, pp 71-77.
2. De Wind, G., Stroeven, P., "Chloride Penetration into Offshore Concrete and Corrosion Risks".
3. Gjorv, O., Tan, K., Zhang, M. "Diffusivity of Chlorides from Seawater into High-Strength Lightweight Concrete", ACI Materials Journal, Vol. 91, No. 5, Sept-Oct 1994, pp 447-452.
4. Gjorv, O., "Important Test Methods for Evaluation of Reinforced Concrete Durability", <u>Concrete Technology, Past, Present, and Future</u>, ACI, 1994.

5. Purvis, R., Graber, D., Clear, K., Markow, M., "A Literature Review of Time-Deterioration Prediction Techniques" Strategic Highway Research Program, National Research Council, 1992.
6. Sandberg, P., Pettersson, K., Jorgensen, O., "Field Studies of Chloride Transport into High-Performance Concrete".

VII – Deployment Potential

1. Revised BDS, Article 8.22, Protection Against Corrosion;
2. Revised Memo-To-Designers 10-5, Protection of Reinforcement Against Corrosion Due to Chlorides, Acids and Sulfates; and
3. Revised Bridge Reference Specification S8-C04(CORR90) Corrosion Control for Portland Cement Concrete.